Operational Concepts of Large Telescopes*

Bruno Leibundgut

European Southern Observatory
Karl-Schwarzschild-Strasse 2
D-85748 Garching
Germany

February 1, 2008

ABSTRACT

The singular way of scheduling at major observatories has favored certain types of astronomy. This has led to the discrimination of certain types of observations which could not be accommodated. It is the goal of future operations to open possibilities for some additional types of observational astronomy. Together with improved observatory operations the new observing modes can provide significant progress in the acquisition of astronomical data. Specifically, the capability to optimally match the schedule to observations should prove a major advantage of service observing.

The VLT data flow project is designed to accommodate these new observing modes together with conventional observing. Simulations and first experience with the ESO NTT will prepare and refine the concepts and procedures foreseen for the VLT. The acceptance of service observing by the astronomical community is of critical importance for this new operational mode to succeed.

Keywords: *telescope operations, operational models, service observing*

1. INTRODUCTION

The efficiency of the new large telescopes to increase our knowledge of the universe and its constituents will depend significantly on how astronomers can utilize them. Only creatively-used and well-operated telescopes will be able to contribute their share to the development of astronomy.

Operational concepts currently discussed by the various large telescope projects can be divided into two main groups which differ mainly by the composition of their user communities. On the one side are the privately-owned observatories with access restricted to a small community of astronomers. For many of these observatories it is most economical and also easiest to continue operation of their telescopes as in the past. The astronomers perform the observations themselves and are fully responsible for the acquired data. Normally they are assisted by experienced telescope operators. In the following this situation will be referred to as conventional observing, often also referred to as classical observing.

*To appear in the Proceedings of the SPIE Conference "Optical Telescopes of Today and Tomorrow," A. Arneberg (ed.), held May 29 - June 2, 1996, in Landskrona/Hven, Sweden

National and international observatories on the other hand are actively experimenting with service, or queue, observing modes[1,2,3]. The attempt is to take better advantage of the varying conditions by combining the best-suited observations independent of individual astronomical projects (cf. [4]). Active interaction with the scientist, who proposed the observations and will analyze the data, during the observing process becomes nearly impossible in this case. The break in the observational chain has to be recovered by operational procedures which enable the astronomers to maintain control over their observations. At the same time interesting new astronomical possibilities emerge with such a mode.

The next generation instrumentation which comes with the new telescopes will also deliver unprecedented data at the cost of increased complexity. Astronomers will need every assistance in preparation and execution of their observations possible. Often when observations are defined in sufficient detail the actual data acquisition can be delegated to the observatory. Many aspects of the advantages of the various modes and the changes involved have been collected in [4].

In the following we will discuss some of the advantages of the two observational modes and develop criteria when they are suited best (§2). The concepts of the VLT specific data flow project which is designed to accommodate the needs of service observing are presented in section 3. Open issues and future directions are discussed in the conclusions.

2. ADVANTAGES — ONE WAY OR ANOTHER

The way current observatories are operated has been developed to efficiently distribute the scarce resource of observing time. Major guidelines are scientific merit of the proposed observations, fair distribution among the subfields of astronomy and – to a certain degree – democracy. Each successful applicant is awarded a certain amount of time at fixed calendar dates to perform the experiment. All the observatory provides is a functioning telescope and instruments with no or little guidance on how to best perform the observations. The observatory's rôle is essentially to administer the resources while developing and maintaining the infrastructure.

With the astronomers guiding the observations at the telescope a quick scientific assessment of the data in respect to their suitability for the project can be done. The vital link of the astronomical observing experience and the researcher is maintained which assures that the data can be analyzed properly. Psychological aspects like the personal involvement of the astronomers with the data acquisition or the astronomers' detachment from their regular work during observing trips can also contribute to the creativity of the scientific process. Advantages of this conventional mode for the observatory are the interaction of observatory staff with the astronomers, the experience brought in by the external users to the observing process, and the possibility to transfer the responsibility of the data acquisition to the astronomers directly. This is particularly important in cases of specialized observations, the outcome of which can not be predicted.

Typical research favored by these operations is based on observations which can be obtained under "regular" environmental conditions delivered by the site and the telescope. Projects which require special conditions are clearly discriminated, unless there is easy access to the facilities as is often the case at observatories with small user communities. There, astronomers typically obtain a larger share of observing time and can mix their own projects to make adequate use of particular meteorological circumstances. Other projects which are typically disfavored in this mode are surveys since the normally large time demands can not be readily allocated at observatories which serve large communities. Another type of project which normally suffers from this conventional scheduling mode are targets of opportunity and general time series observations of objects with time scales of weeks or months. Smaller communities, where the data exchange is organized informally, have been able to arrange for such occasions, but the larger observatories had to introduce formal and often awkward rules to handle these situations.

The previous paragraph lists a few astronomical reasons why it would be advantageous to change scheduling procedures. The exploration of parameter space mostly inaccessible so far can add significantly to astronomical progress. It is this widening of the observational options which is scientifically most interesting and leads to the discussion of service observing. The possibility to select observations matching the prevailing conditions best will enable projects depending on special circumstances. This observational edge may speed up results which otherwise would rely on the meteorological luck of the draw. Surveys can be carried out mixed with other observations. It has to be noted that most massive surveys have been obtained in service mode as the example of the Palomar Observatory and the ESO/SERC Sky Surveys, the current near-IR surveys (DENIS and 2MASS), or the searches for massive halo objects (MACHO, EROS, OGLE) with their scientific spin-offs show. Another observational niche difficult to access at large observatories is the monitoring of variable objects and observations of targets of opportunity. Such synoptic observations can very easily be fitted into a flexible scheduling process, which is a prerequisite for service observing. A small number of objects spaced around the sky requiring just a few observations can easily be accommodated in service mode, while they may not reach critical program size for time allocation in the conventional case. Another aspect more difficult to quantify may be the more efficient use of the available time as programs will be performed to the exact amount of exposures needed. Finer adjustment to the moon phases gains some dark hours which are often lost when programs are scheduled conventionally in blocks of complete nights[5,6]. Observing projects may improve by the needed preparations which entail a complete road maps of how the data will be analyzed. This should happen even though there will be no formal requirement to do so. A further possible spinoff is the availability of an extensive archive of observations. Archival research, although not yet a primary resource, may contribute significantly to projects where the combination of data from different wavelength regimes is advantageous.

While there remain many astronomical projects which clearly are best served in conventional mode, the above examples show that there are a few reasons why it may be interesting to explore some other operational modes with new telescopes. The selection of the most appropriate observing mode for each project will be an important decision which will need careful evaluation by the astronomer.

The move to new operational schemes must be driven by improvements in the scientific process. Many discussions on operational issues have focussed on advantages for observatories, which are not negligible, but can not by themselves justify the proposed, stringent changes. The astronomical community must embrace the new opportunities for success. It should also be noted that all observatories plan to offer both observing modes leaving all options open.

3. INFORMATION EXCHANGE IN A COMPLEX OBSERVATORY THE VLT DATA FLOW

Removing the astronomers from the actual observations at the telescope implies that other means must be provided to retain their control over the observational process. The development of the procedures to guarantee the astronomer's participation has started at ESO within the On-Line Data Flow project (see also [1]). Its basis was developed in the VLT Science Operations Plan[5] and a document which defines the astronomical requirements on the observatory information chain[7]. The link between the astronomer and the observatory should be close and transparent. It also should remain flexible.

There are a few very clearly separated stages in the astronomical information and data cycle[1,7]. Each phase has demands and services which have to be identified and carefully combined. The definition of the observing program and its scientific evaluation by peers as well as the definition of the individual observations should be provided by the astronomy community. The observatory solely supports and administers this process. Scheduling of programs in conventional mode and the observations in service mode, however, are performed by the observatory. The demand for exact observation definition drives the requirement for the second phase of the astronomer – observatory interaction. To built a schedule which optimally matches the prevailing conditions with the obser-

vational requirements the scheduler will need accurate input from a meteorological site monitor, telescope and instrument status, and astronomical restrictions (e.g. moon phase). The actual observations will be handled by specific telescope, instrument, and detector software[8] which will return the data products (frames and logs) to the data flow. The further data handling involves archiving and pipeline processing for provisional quality control. All these processes fall into the responsibility of the observatory.

These considerations led to the adoption of a two-layered system relaying information among the various subprocesses. The VLT could be run from the control system alone without the data flow superstructure, but the technical description of the instrument and the interaction with the scheduling process are considered too detailed and cumbersome for astronomers who infrequently interact with the system. The data flow acts as the intermediary between the astronomers and the technical software. There are four fundamental agents the data flow is connecting: the astronomer, the scheduler, the technical software, i.e. the observing facilities, and the archive. The VLT concept does reflect their basic needs. "Observation Blocks" contain the complete information relevant for an individual observation[1,9]. An observation in what follows is considered a single pointing of the telescope with a specific instrument setup to acquire a coherent data set. Apart from obvious quantities, like coordinates and instrumental setup, observation blocks can also contain global requirements of importance to the scheduler, general comments of interest to the observer, and links to reduction procedures or quality control. A specific feature is the modularity by which observation blocks can refer to other observation blocks to combine observations. It is thus possible, e.g., to link regular observations with the acquisition of calibration data.

All information on the instrument and its operation during the observation is encapsulated in "instrument templates[1,9]." These structures define commonly used setups and are embedded in the observation blocks. The astronomer defines the specific parameters of the setup in a template parameter file which accompanies the template. This should ease the astronomers' interaction with the VLT system as many details of instrument operations can be served by the templates. Some observations will not be offered with templates in which case the option to drop to the level of the VLT technical software is still available.

Astronomers whose proposals successfully passed the selection process will hence have to prepare the observation blocks and the templates for each observation in their program. This preparatory phase is foreseen for all proposals and guarantees the close involvement of the astronomers. Even conventional observations will be prepared in this preparatory phase to familiarize the astronomers with the system. In this case the astronomers will use their observation blocks at the telescope during their assigned nights. During service time all available observation blocks are provided in a central database polled by the scheduling software. The scheduling is a very complex process which currently is not yet fully defined for the VLT. Since the best performance is achieved only when sufficient information is available and the detailed procedure depends on many different sources, it is important to collect as much intelligence as possible. Observations with detailed descriptions of their requirements are more likely to achieve the requested quality as they can be scheduled accordingly.

A long-term plan for the semester or a fair fraction of it schedules conventional observing runs and defines the requested instrument setups. This will be required even with instrument changes becoming possible at short notice as special filters or gratings will have to be mounted ahead of time. Flexible scheduling itself will rely on local information sources which describe the prevailing conditions of and at the observatory. Meteorological input is provided by a site monitor. Image quality assessment (including sky background), possible forecast of critical parameters (e.g. cloud cover, precipitable water vapor, seeing) will provide the basis of the selection process. ESO has maintained a program to characterize prevailing meteorological conditions over the past several years[10] and is embarking on a project to forecast some of the meteorological parameters on the basis of a few hours. Options for operations with limited information have to be developed as well.

An important aspect of the scheduling process is the underlying criteria which govern the selection. This is largely unexplored territory for all observatories with the notable exceptions of HST and the NOAO operations of the WYIN telescope[2]. Important results are expected from simulations with mock projects which encompass a large set of observations and a variety of requirements. Although it will be impossible to fully simulate the scheduling of a semester describing the creativity of programs of real astronomers and vagaries of real-time

operations, simple strategies can be tested and compared. The effect of operational overheads, instrument changes, decision time scales, importance of program completion, and weighing of different conditions can be explored ahead of time.

The telescope and instrument software returns raw data frames to the data flow. Archiving and further processing complete the cycle. The data archive captures all relevant information for a given observation. This includes the original request contained in the observation block and template together with the actual conditions. Other relevant observations, e.g. calibrations and standard star data, linked to the project are also stored in this central place. The astronomers will receive (or retrieve) their data from this archive. Once data become public it will be accessible by the whole astronomical community.

At the VLT a routine pipeline processing of all data obtained in service mode and, possibly, conventional observing will be attempted. The pipeline results are used for a quick assessment of the data, potentially influencing the further observations of the night. They will provide preliminary removal of instrumental and detector effects. The quality control will follow the pipeline reductions to ensure that the observations correspond to what was requested.

To test the concepts and procedures of the data flow a set of reference proposals has been defined. These observational projects with some scientific background have been designed to cover a large range of observational requests and techniques. They will be used to check the interfaces and the interactions of the various parts of the data flow. For a first check they will play the rôle of external astronomers. The reference proposals can also be used for simple scheduling simulations.

4. BUILDING THE EXPERIENCE

The complexity of the operations of modern large telescopes should not be underestimated. The required information exchange between the astronomers and the observatory represents a vital link to assure that the observatory delivers what is requested and expected by the astronomers. The future will look different for the regular user even observing conventionally. Telescope operations have been long ago delegated to specialists and astronomers have accepted the help provided by telescope operators. The complexity of the instrumentation and the observational procedures will further emphasize the astronomers' understanding of technical aspects. It should be the goal of the operations to keep the astronomers' interaction with the facilities and the staff as simple as possible. Every possible help the observatory can provide should be available to support the astronomers in their scientific experiments. They should be able to concentrate on the observational aspects rather than technicalities. Nevertheless, the astronomers will have to be provided with sufficient information so that they can understand and assess their data in all observational aspects.

To assure acceptance of these conceptual changes the collaboration of the astronomical community has to be assured. The early involvement of future users of the system can only improve the operations. Several science test cases for the VLT have been solicited from the European astronomical community. These test cases will be used in addition to the internal reference proposals to test the procedures. They have the additional advantage to be based on real science projects and the external astronomers are experts in the requested observations who can provide helpful criticism. Since the data flow is the VLT's interface with the astronomical community it will largely define the perception of the observatory. The input from users is essential for a successful development.

The recommissioning of ESO's New Technology Telescope (NTT) will be combined with the start of service observing at ESO. Several programs have been approved and the data flow system will undergo a first real test before the end of 1996. At first, the service mode will be restricted to direct imaging in the optical, some of the operationally least demanding observations. Spectroscopic observations in the service mode will offered only during the following semester.

5. CONCLUSIONS

The introduction of new observing modes in combination with the improved instrumental capabilities is a daunting task. The prospective advantages are significant and may provide an important observational edge over other approaches. At the same time the success of the experiment almost entirely depends on the acceptance by the community. The astronomers will have to learn to optimally use the new possibilities. Since many of the changes have been initiated by the observatories it will be their rôle to convince the rest of the community of the gains. A fundamental requirement is the smooth operation of the observatory and the improved data quality has to become an essential argument.

At the VLT the data flow will link the observatory to the astronomers and expand the interaction between them. It presents the astronomers with all observational possibilities and lets them make best use of the facilities. An integrated approach has yielded a system which will entail all operational aspects. It should be noted that there exists a clear separation between the needed infrastructure, the data flow, and the operational model. A flexible data flow system will provide the options to built and improve operational models without major limitations.

Definition of an operational model for the VLT will have to tackle open questions like the scale of the preparatory phase, the exact criteria for the scheduling process, and the degree of pipeline processing. A convincing model must include compelling reasons for the expanded preparatory phase. Flexible scheduling drives most of the complexity of the VLT data cycle. The operational model will have to set the astronomical priorities, possibly based on the results from simulations.

First lessons from simulating the information and data cycle with mock projects will be followed by service operations of the NTT in early 1997. Further refinement in the VLT environment at the NTT[11] will provide a solid basis for a successful start of service observations at the VLT itself.

Service observing will remain an experiment for the first few years. It must not be seen in isolation as it is introduced to compliment the current observational capabilities. Observing with the VLT will be possible in conventional as well as service modes. The selection of which mode suits the program and its observation best should ideally be based on astronomical criteria. This can be achieved when sufficient trust has been built through reliable delivery of high-quality data.

6. ACKNOWLEDGEMENTS

Building the operations of a complete observatory is not a small task and depends on many people. The views expressed in this article are based on discussions with many colleagues at ESO. The data flow project is headed by P. Quinn and includes M. Albrecht, E. Allaert, D. Baade, A. M. Chavan, P. Grosbøl, M. Peron, G. Raffi, and J. Spyromilio. They have been instrumental in developing some of the ideas. I am also grateful to A. Renzini, the VLT project scientist, for many discussions regarding these issues.

7. REFERENCES

[1] Peron, M. & Grosbøl, P. 1996, these proceedings

[2] Silva, D. 1996, NOAO Newsletter 47

[3] Puxley, P. et al. 1996, these proceedings

[4] Davies, J., Robson, I., & Boroson, T. (eds.) 1996, *New Observing Modes for the Next Century*, ASP Conference Series 87

[5] Baade, D. 1995, “VLT Science Operations Plan”, VLT-SPE-ESO-10000-0441, Garching: ESO

[6] Boroson, T. 1996, in *New Observing Modes for the Next Century*, eds. J. Davies, I. Robson, and T. Boroson, San Francisco: ASP Conference Series

[7] Grosbøl, P. & Leibundgut, B. 1995, “VLT On-Line Data Flow: Requirement Specification”, VLT-SPE-ESO-10100-0749, Garching: ESO

[8] Wirenstrand, K. & Raffi, G. 1996, these proceedings

[9] Leibundgut B. 1996, in *New Observing Modes for the Next Century*, eds. J. Davies, I. Robson, and T. Boroson, San Francisco: ASP Conference Series

[10] Sarazin, M. 1996, in *New Observing Modes for the Next Century*, eds. J. Davies, I. Robson, and T. Boroson, San Francisco: ASP Conference Series

[11] Wallander, A. 1996, these proceedings